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(54) ROTARY POSITIVE-DISPLACEMENT FLUID MACHINE

(71) We, NORTHWESTERN UNIVERSITY, of 633 Clark Street, Evanston, Illinois 60201, United States of America, a Corporation organized under the laws of the State of Illinois, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a rotary positive-displacement fluid machine. The machine of the invention is particularly useful as a pump, motor, engine or other fluid (e.g. gaseous) pressure producing or responsive mechanism.

In this specification what we mean by a convoluted vane of Mobius type is a vane in the form of a helical strip of material twisted once about its longitudinal axis and having ends which are brought into a juxtaposed position so that the two planes containing the ends of the strip are wholly or substantially parallel with both each other and the helix axis, and said planes wholly or substantially coincide with each other.

According to the present invention a rotary positive-displacement fluid machine comprises a rotor, rotatably mounted within a cylindrical casing, axially displaced peripheral portions on the rotor in fluid sealing relationship with the casing, an annular concave waisted portion formed in the rotor intermediate the displaced peripheral portions, a rotatable circular disc part of the circumference of which is complementary with the curvature of the concave waisted portion and having a pair of slits extending inwardly of the periphery of the disc, a convoluted vane of mobius-type (as hereinbefore defined) extending in a single helical turn about the waisted portion of the rotor and being in fluid sealing relationship with the waisted portion and the casing, said vane arranged so that it projects into one of the slits in the disc for sliding movement there-through the vane configuration being such that on rotation of the rotor the disc rotates and as one slit is disengaged from the vane

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the other slit engages the vane and so on, an inlet for fluid to within the casing and an outlet for fluid from the casing.

The invention also includes a multi-chambered fluid-actuated engine comprising in combination, first and second rotors each having a semi-circular concave waisted portion and bounded by a cylindrical casing coaxial with a central axis of the rotor to define an annular pocket a convoluted vane of Mobius-type (as hereinbefore defined) in each rotor extending in a helical turn about the waisted portion and being in fluid-sealing engagement with the waisted portion and the casing, an annular boss, substantially semi-circular in transverse cross-section, affixed to, and extending radially inwardly of, the cylindrical casing of each rotor, the boss of each rotor ensuring fluid-sealing engagement between the vane and the casing, a circular rotatable disc common to the first and second rotors which has substantially half of its circumference complementary with the waisted portion of each rotor, and is formed with a pair of diametrically opposed slits extending radially inwardly of the periphery thereof, the vane of each of the first and second rotors projecting into one of the pair of diametrically opposed slits for sliding movement there-through, the configuration of the vane being such that on rotation of the rotors the disc rotates and as one slit is disengaged from a vane the other slit engages the vane and so on, a fluid pressure inlet to the annular pocket of the first rotor, a fluid pressure outlet from the annular pocket of the second rotor, and sealing means carried by the disc about its circumference and adapted to abut, and to conform resiliently to the waisted portion of each rotor, the sealing means comprising a strip that is substantially T-shaped in cross section the stem of the T being seated within a radial and circumferential groove extending inwardly of the circumference of the disc, and the cross bar of the T abutting and conforming to the shape of the waisted portion of each rotor.

A fluid engine embodying the present

invention can be powered by gas or other compressible medium under pressure to generate continuous torque directly, without use of reciprocating motions. The basic device consists of a portion of a Mobius Strip, formed as a vane mounted on a wasp-waisted spindle. This assembly, which is preferably all one unit, is slidably received within a cylindrical cavity, the top and bottom rims of the spindle sealing the top and bottom of the cavity, and the edge of the vane forming a sliding seal against the walls defining the cavity.

The second, and only other, moving part of the engine is a disc with a hub, the disc being slotted in two places along a diameter. Either slot will slip over the vane so that the disc can fit in against the inner wall of the spindle forming a seal to the spindle and its attached vane. In a preferred embodiment of the invention the disc fits into the indented side of the spindle for half its diameter and the protruding half is accommodated by a chamber machined into the inner wall of the housing defining the cavity. This chamber cannot communicate with outside atmosphere, so it is dimensioned to fit the disc closely. To facilitate assembly, the housing is preferably fabricated in two parts. It will be appreciated that the slots in the disc must permit movement of the vane through the slots with minimal friction. Techniques found suitable include forming the slots to include a "twist", radiusing the slots to make only a line contact with the vane, or employing flexible lining material in the region of contact.

Preferred forms of the invention will now be described by way of example with reference to the accompanying drawings in which:—

Figure 1 is a side elevational view of a machine embodying the invention and indicating, generally, the disposition of component parts in the housing;

Figure 2 is an end elevational view of the machine illustrated in Figure 1 and showing the projecting disc-enclosing chamber;

Figure 3 is a top plan view of the machine of Figure 1;

Figure 4 is a cross-sectional view taken on the line 4—4 of Figure 1;

Figure 5 is a cross-sectional view, somewhat enlarged, taken on the line 5—5 of Figure 3;

Figure 6 is a diagrammatic, perspective view showing the mechanical relationship and the interengagement of parts of the machine, including the spindle, the casing, and the slotted disc;

Figures 7 to 10 are diagrammatic representations of stages in the sequence of spindle rotation;

Figure 11 is a diagrammatic vector-like representation indicating the relative mag-

nitudes and angular relationships of spindle and disc rotation as well as vane pitch;

Figure 12 is a perspective view of a preferred embodiment of the spindle-engaging disc and a bead for effecting a gas-tight seal between the disc and the spindle;

Figure 13 is a cross sectional view of the sealing bead of Figure 12 seated in an annular disc-encircling groove formed in the periphery of the disc;

Figure 14 is a cross-sectional view, similar to Figure 13, but indicating schematically the limiting flattened disposition of the sealing bead as assumed upon stressed engagement with the wall of the spindle;

Figure 15 is a fragmentary perspective view showing a preferred arrangement for sealing between the rotating disc and the spindle-encircling vane, and

Figure 16 is a diagrammatic representation of the operation of the machine as an internal combustion engine.

In the embodiment of the invention illustrated, the motor 20 includes a rotary assembly 24 consisting of a spindle 26 encircled by a convoluted free-ended vane 30. At its upper and lower extremities the spindle 26 is formed with end plates 42 and 44 the rims of which seal in bearing relationship against the surrounding wall 46 of a housing or casing 50 having a generally cylindrical bore, whereby the spindle 26 is rotatable within the housing 50. The exposed lateral wall 54 of the spindle 26 is a concave surface of revolution of a semi-circle about the rotor axis, and the facing inner wall surface 60 of the housing 50 is a right circular cylinder.

The vane 30 is of uniform thickness and takes the form of a Mobius strip which is severed transversely, so that it has two parallel straight-edged free ends 70, 72 and executes a single helical turn about the spindle 26, the ends 70, 72 being equi-distant from the axis of the wall 54. The physical orientation of the convoluted vane or strip 30 about the spindle 26 is such that one longitudinal edge 64 of the strip 30 is in fluid-sealing engagement with the concave surface 54 of the spindle 26. In a preferred form of the invention, the vane 30 itself is firmly fastened to the spindle 26 or is formed integrally therewith. The other longitudinal edge 68 of the strip 30 bears in fluid sealing engagement against the facing inner surface 60 of the housing 50. As seen most clearly in Figure 6, in describing its path about the spindle 26, the strip 30 extends between the base plate 42 and the upper plate 44 of the spindle 26 to traverse the full expanse or height of the arcuate wall 54. The upper and lower ends 70 and 72 of the strip 30 are in substantially vertical alignment, lie in substantially the same plane, and bear against the abutting wall 46 of the

housing 50 in sliding, fluid-sealing engagement therewith.

Referring now to Figure 6, the fluid motor embodiment of the invention illustrated includes an output disc 80 which is circular in form and has the same radius of curvature as the semi-circle which defines the surface contour of the spindle wall 54, so that the longitudinal curvature of the spindle corresponds to the peripheral curvature of the disc. A hub 84 of the disc 80 serves conveniently as an output shaft. The disc 80 is formed with a pair of diametrically opposed slits 88 and 90 extending inwardly of its periphery and sized to receive the strip 30 therein for slidable passage therethrough and in fluid-sealing engagement therewith. The slits 88 and 90 are preferably radial but may be inclined at an angle to the radial direction provided that the angle of the convolute vane 30 is correspondingly arranged.

If the disc 80 is to rotate at constant angular velocity while the spindle 26 is also rotating at constant angular velocity, then the slits 88 and 90 in the disc be cut so that the walls of the slits are planes making an angle with the plane of the disc if the vane is to be sealed into the slits. The reason is that at any given radial distance on the disc from the axis of the disc, the vane will pass through the slits at varying angles as rotation proceeds. This can be seen from the following analysis:

At constant angular velocity, the periphery of the disc has a tangential velocity of a certain magnitude. Likewise, at the point where one radial element of the disc intersects or reaches the surface of the spindle, the spindle surface has velocity of its own at right angles to the disc tangential velocity. The local direction of the vane surface must lie along the resultant of these two vectors (Figure 11). A pitch angle may be defined, at the root of the vane, as an angle which is maximum at this point and diminishes toward zero along the slot in the disc as the center of rotation of the disc, and the free edge of the vane, is approached.

As indicated schematically in Figure 11, the tangential velocity of the spindle surface is least at the narrowest part of its waist, and greatest at the periphery of each end plate. Hence, the pitch angle of the vane (indicated as P), measured from a normal to the plane of the disc, is greatest at the waist of the spindle and least at the periphery of each end plate, if the tangential velocity of the disc is maintained constant relative to that of the spindle. A disc having appreciable thickness, therefore, cannot have its slots formed for a close sliding fit over the surface of the vane under the restriction of constant velocity, because the angle made by the vane and the surface of

the disc varies during rotation. Without special arrangements to attain a surface-to-surface seal, only a line seal could be achieved, for example, by making the thickness of the vane variable to accommodate the varying pitch angle of the vane to the fixed slot width, and by rounding the edges of the slit opening.

The structure described herein provides a sealing effective to maintain a broad-area disc-to-vane seal under conditions of moderately varying pitch angle. Clearly, the less the ratio of maximum to minimum radii of rotation of the spindle surface, the less variation in pitch angle there will be, and the less stringent will be the requirements for flexible seals of the type described below.

In the preferred embodiment of the invention illustrated, the method of maintaining a disc-to-vane seal may be to bond or apply a relatively soft compressible material to the inner faces of the disc slits, to take up variations in pitch angle while maintaining an area contact against the vane. A better method, though possibly of somewhat greater difficulty in execution, is to drill approximately radial holes into the disc so that when the slits are cut, each face of the slits will contain a groove 100 of round cross-section (see Figure 15). Into this groove may be slid a long thin cylinder of flexible material 102 having a flat 104 along its entire length. The flat bears against the vane surface, and the cylindrical part bears against the groove surface and partially rotates as the pitch angle and hence the twist of the slot is required to change. Just enough of the insert protrudes out of its groove to permit contact of its flat surface with the surface of the vane, the flexible material being capable of enough twist to accommodate the variation of pitch angle of the vane from the periphery of the slit to its most central part. This approach permits the use of flexible material of maximum strength for the insert, exposing a minimum of it to pressure from the working fluid. This insert may be a thin-walled metal extrusion if the changes in twist are not extreme. If preferred, softer material may be employed for greater flexibility. Bearing surfaces may be faced with metal.

In Figure 6, a spindle 26 is shown inside a housing 50. This spindle fits into a generally cylindrical cavity in the housing. The walls of the cylindrical cavity and the wasp-waisted form of the spindle create an annular cavity 112 surrounding the spindle. The disc 80 extends into this cavity and seats against the waist 26 of the spindle. A vane 30 that is integral with the spindle passes through a slot 88 in the disc. A second slot 90, on the same diameter as slot 88, may also engage the vane at a different time. As the spindle rotates, the disc rotates about

an axis tangent to the cylindrical cavity in the housing, and at right angles to the axis of symmetry of the spindle. In the preferred form of the invention illustrated, the disc is disposed to present half of its diameter into the cavity 112. The hub 84 prevents the spiral free edge of the vane from extending all the way to the wall 60 (Fig. 5) of the cylindrical cavity in the housing. Accordingly, an annular boss 116 is formed on the housing wall 46 and extends therearound ensuring proper sealing between the vane 30 and the casing 50, the radial intrusion of the boss 116 into the cavity 112 being equal to that of the disc hub 84. That half 120 of the disc 80 not in engagement with the spindle 26 and projecting generally radially outwardly therefrom extends into and is rotatably received in bearing and fluid-sealing engagement within a cooperating chamber 126 (Fig. 4) formed in the casing 50. Fluid input and exhaust passages 130 and 132 extend through the casing wall 136 and communicate with the interior cavity 112. The ports 140 and 142 opening into the cavity 112 are on opposite sides of the disc 80 and are displaced axially within the cavity 112, the positioning of the ports 140 and 142 being such that they are wiped by respective ends 70 and 72 of the strip 30 as the latter rotates within the housing 50.

A diagrammatic representation of the functioning of the rotating spindle and vane and its phased relationship with the slotted disc 80 is shown in Figures 7 to 10. As indicated, the spindle-vane assembly 24 is shown as turning counter-clockwise, as viewed from above. The disc 80 will then revolve clockwise.

When the spindle-vane assembly 24 turns once, the disc 80 will make half a revolution. As the disc slot 88 which has been engaged with the vane 30 and disappears into the housing 50 (Figure 9), the other slot 90 appears and picks up the leading end of the vane 30. Thus for nearly the entire revolution, one of the slots is engaged with the vane and the other is hidden in the chamber 126 in the wall of the housing 50.

In Figure 6 can be seen a chamber in the lower foreground labelled "A". This chamber is formed by the vane 30, the spindle 26 carrying the vane, the disc 80, and the cylindrical wall 46 of the cavity in the casing or housing 50. The chamber is roughly shaped like a pyramid with a triangular base and a chisel-shaped apex, bent around the spindle 26.

As the spindle 26 rotates in the direction shown by arrows, this chamber increases in volume for one full revolution. Therefore, a fluid under pressure introduced into this cavity near the disc will cause torque to be generated in the direction of the arrows.

At the end of one full revolution, the fluid in this chamber finds itself in a new chamber, sealed off when the trailing edge of the vane finally leaves the slot, chamber B. This chamber is bounded by the vane 30 and the wall 46 of the housing 50, but now both ends are sealed off by the disc 80.

Chamber B will retain its identity for one full revolution, at which point it becomes the third chamber C, which decreases in volume essentially to zero. The fluid in this third chamber is vented from the motor through exhaust tube 132. Alternatively, the fluid may be returned for re-use. The term "fluid" is used in the conventional sense, an example being a gas.

The establishment of a positive, effective seal between the disc 80 and the spindle wall 54 is important in ensuring efficient operation of the assembly. Several preferred sealing arrangements are set forth in detail below.

The surface of the spindle is convex at its narrowest point but essentially flat adjacent the periphery of plates 42 and 44. Hence the edge of the disc, if rigid, is restricted to a line contact with the spindle. In Figures 12 to 14, the effectiveness of the gas seal is enhanced through the use of a pair of beads, bands or webs 150 of compressible or flexible material which automatically adapt or conform their shape to maintain an area or zone of contact between the disc 80 and the spindle 26.

The outer edges 152 of the disc 80 between the slots 88 and 90 is grooved 156, and a longitudinally curved bead 150 that is T-shaped in cross-section is inserted into each groove 156 with the stem 160 of the T in the groove and the crossbar 164 of the T located between the disc edge 152, and the spindle wall 54. The crossbar portion is preformed so as to be strongly concave at its face opposed to the stem 140. When pressed between disc 80 and spindle surface 54, the arcuate crossbar 164 will thus force itself into conformity with the spindle wall 54 anywhere between center (where the crossbar 164 will be curved) and periphery (where the crossbar 164 will be flattened), all as indicated schematically in Figures 13 and 14.

The sealing inserts or beads 150 may be fabricated of hard, wear-resistant metal, too stiff to permit great degrees of flexing. In such cases the sealing inserts 150 may consist of a plurality of generally flat half-rings stacked or arranged like laminations, but formed independently, and inserted in place in the disc grooves, each such insert being shaped to follow a natural radius of curvature somewhat longer than that of the disc edge so as to tend to spring resiliently outwardly against the spindle wall 54. Each insert would make a line contact with the

spindle wall, and the multiplicity of such contacts would provide the necessary quality of gas seal. Each of the rings would occupy a position corresponding to that occupied by the stem 160 of the T-shaped bead 150 of Figure 12 (see Figure 13) and would be retained by slightly deeper penetration into the disc of projections at each end of the semicircle.

There are two important factors which make the machine of the invention when used as an engine more efficient than other types of engines, particularly when the working fluid is steam. First, whether steam or some other gas is used, when the engine is operated by means of a compressed gas the work done near the end of the stroke is greater than that in a reciprocating-piston engine, because the area of the "piston" increases uniformly throughout the stroke. Assume that at the beginning of a revolution, a fixed quantity of compressed gas is introduced, which then expands for the remainder of the stroke. When the gas pressure is lowest, the area is greatest, so that useful work can continue to be extracted despite the drop in pressure. This means that the final temperature of the exhaust gases can be made lower, with a corresponding improvement in theoretical efficiency. The principle involved is the same as that in a multi-stage steam engine having high pressure and low pressure pistons, but the "staging" is continuous and occurs during a single stroke.

As a steam engine, this device can provide a portion of the ideal cycle that cannot be realized in a piston engine. After expansion of the steam in the first chamber, and a dwell-period of one revolution, the expanded steam can be compressed in a third chamber, being condensed under this pressure to the status of water droplets. This compression is powered (to the extent that power is required) by the power stroke which occurs in chamber A each revolution. After the midpoint of a revolution, the effective piston area of the inlet or power chamber is larger than that of the outlet chamber; hence, a continually increasing mechanical advantage than exists for efficient compression of the condensing vapor. Thus it appears feasible to do away with the separate condenser that is commonly employed, avoiding the need for a temperature drop that produces no useful work. Efficiency will further be improved by the fact that the final compression stroke will produce a rise in temperature in the third chamber, which will somewhat reduce the flow of heat through the vane from the expanding gases in the power chamber, heat which otherwise is altogether lost in an external condenser, and does not contribute to mechanical energy output.

For regulating the flow of compressed fluid or gas into the power chamber by means other than allowing the vane to uncover the inlet hole, valving may be accomplished simply by placement of passageways in the spindle, in the housing, or in the shaft of the slotted disc. By this means both compression and expansion can be optimized.

The machine can be used as an internal-combustion engine by the simple addition of a spark-plug and valving, so that a fuel-air mixture can be introduced into chamber A during the first few degrees of expansion, the chamber then being valved shut and the mixture ignited. Again the theoretical efficiency will be higher than that in an analogous reciprocating-piston engine because of the increase of piston area as the pressure drops. The fact that a power stroke lasts for one full revolution means that for a given engine speed the burning time allowed is four times as long as in a four-stroke cycle engine and twice as long as in a two-stroke cycle engine. The engine of the invention is essentially a one-stroke cycle engine, since exhaust and power strokes occur simultaneously. The operation of the engine of the invention as an internal combustion engine as indicated diagrammatically in Figure 16.

For higher efficiency as an internal-combustion engine, the motor should be supplied with a pressurized and hot fuel-air mixture. This is conveniently accomplished by using a second rotor 170, geared to the first 174, as a compressor pump. This compressor 170 draws a mixture into chamber A, allows one revolution for mixing in chamber B, and then compresses the gas in the third chamber, raising pressure and temperature. Valving (not shown) is used to release this compressed mixture into chamber A of the motor half for the proper portion of the cycle (so that ignition does not occur with this chamber at zero volume). Only one slotted disc 180 is required for the dual arrangement, since the half of the disc not used in the motor is free to serve the other rotor which is being used as a compressor. The spindles are geared together through interengaging spur gears or other coupling means. Transfer of torque via the slotted disc would be inefficient, because of sliding friction. Thus in this embodiment one rotor constitutes a pump including a compression chamber and the other rotor the combustion chamber.

The manufacture of the vane-spindle combination may be carried out starting either with a cylindrical workpiece or a rough casting. The principle of generating the vane and spindle as a single unit depends on using a tool which rotates in synchronism with the rotation of the workpiece through gearing or electronic control. The tool is placed

on the same axis as the axis of the slotted disc, and as it rotates, a cutter is gradually extended radially from this axis, cutting deeper and deeper into the workpiece and making a helical slot. The workpiece and tool must be geared together, and the tool must be capable of allowing gradual extension of the cutting edge along a radius. The slot is then progressively widened to produce, finally, the vane, by altering the phase relationship of tool and spindle.

The slotted disc bears all the reaction force from the motor torque, and must transmit this force to the housing. Therefore, the disc is preferably mounted by its hub onto a shaft that is supported on thrust bearings in the housing.

This machine can be made into a highly efficient right-angle drive with a reduction ratio of two to one. One of several possible configurations would involve only the mounting of conical rollers on ball bearings in the slots of the slotted disc. This would change the sliding friction to rolling friction, and power would be transmitted efficiently from the spindle to the shaft of the disc.

Power input and output from this machine whether used as a motor, right angle drive, or pump, would require a shaft through the spindle. Bearings on this shaft could be used to serve as locators for the spindle, the seal around the upper and lower rims of the spindle then being accomplished with inset material, metal or high-temperature compressible material. Friction at this seal will be reduced greatly by separate suspension of the spindle in bearings, since the torque is not balanced about the axis of the spindle. Changes in geometry can be made by changing the radius of the waist of the spindle without changing the radius against which the disc bears. Thus it would be possible, when employing this device as a motor, to vary the torque obtained for a given disc size and inlet pressure, and for that matter to design configurations yielding different amounts of torque for a given disc size and inlet pressure, a torque increase being obtained by increasing the waist radius of the spindle and thus moving the disc farther away from the axis of the spindle.

WHAT WE CLAIM IS:—

1. A rotary positive-displacement fluid machine comprising a rotor, rotatably mounted within a cylindrical casing, axially displaced peripheral portions on the rotor in fluid sealing relationship with the casing, an annular concave waisted portion formed in the rotor intermediate the displaced peripheral portions, a rotatable circular disc part of the circumference of which is complementary with the curvature of the concave waisted portion and having a pair of slits extending inwardly of the periphery of the disc, a convoluted vane of Mobius-type (as

hereinbefore defined) extending in a single helical turn about the waisted portion of the rotor and being in fluid sealing relationship with the waisted portion and the casing, said vane being arranged so that it projects into one of the slits in the disc for sliding movement therethrough the vane configuration being such that on rotation of the rotor the disc rotates and as one slit is disengaged from the vane the other slit engages the vane and so on, an inlet for fluid to within the casing and an outlet for fluid from the casing.

2. A multi-chambered fluid-actuated engine comprising in combination, first and second rotors each having an annular semi-circular concave waisted portion and bounded by a cylindrical casing coaxial with a central axis of the rotor to define an annular pocket, a convoluted vane of Mobius-type (as hereinbefore defined) in each rotor extending in a helical turn about the waisted portion and being in fluid-sealing engagement with the waisted portion and the casing, an annular boss, substantially semi-circular in transverse cross section, affixed to, and extending radially inwardly of, the cylindrical casing of each rotor the boss of each rotor ensuring fluid-sealing engagement between the vane and the casing, a circular rotatable disc common to the first and second rotors which has substantially half of its circumference complimentary with the waisted portion of each rotor and is formed with a pair of diametrically opposed slits extending radially inwardly of the periphery thereof, the vane of each of the first and second rotors projecting into one of the pair of diametrically opposed slits for sliding movement therethrough, the configuration of the vane of each rotor being such that on rotation of the rotors the disc rotates and as one slit is disengaged from a vane the other slit engages the vane and so on, a fluid pressure inlet to the annular pocket of the first rotor, a fluid pressure outlet from the annular pocket of the second rotor, and sealing means carried by the disc about its circumference and adapted to abut, and to conform resiliently to the waisted portion of each rotor, the sealing means comprising a strip that is substantially T-shaped in cross section the stem of the T being seated within a radial and circumferential groove extending inwardly of the circumference of the disc and the cross-bar of the T abutting and conforming to the shape of the waisted portion of each rotor.

3. An engine according to claim 2 wherein one rotor constitutes a pump including a compression chamber and wherein the other rotor includes a combustion chamber, fluid carrying conduit means being provided for communication between the two rotors.

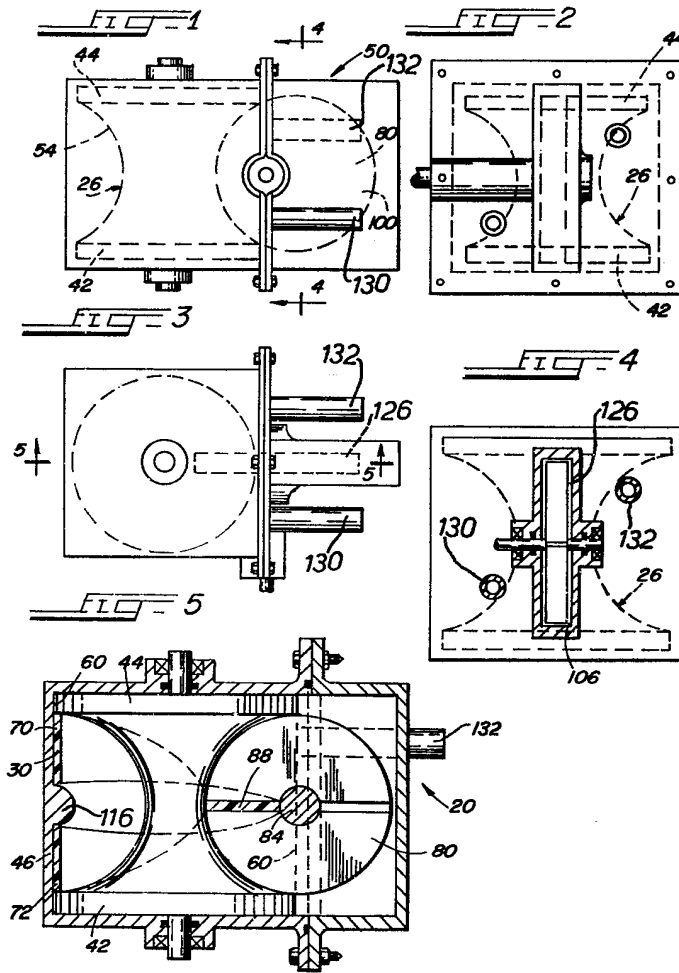
4. A fluid actuated motor substantially

as hereinbefore described with reference to Figures 1 to 15 of the accompanying drawings.

5. A multi-chambered fluid actuated engine substantially as hereinbefore described with reference to the accompanying drawings.

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COMPLETE SPECIFICATION

3 SHEETS

*This drawing is a reproduction of
the Original on a reduced scale*

Sheet 2

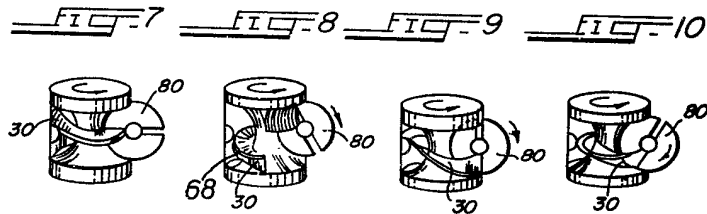
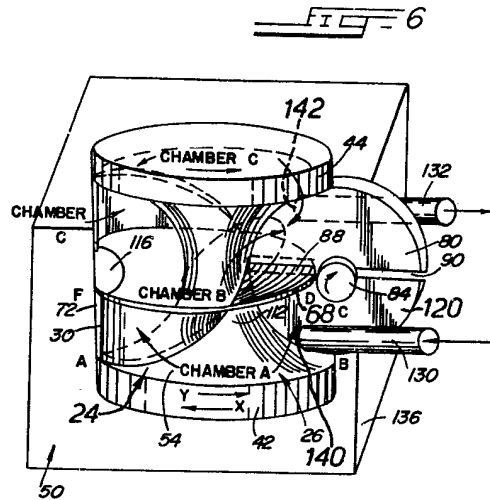


FIG. 11

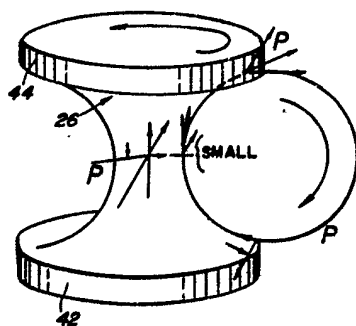


FIG. 16

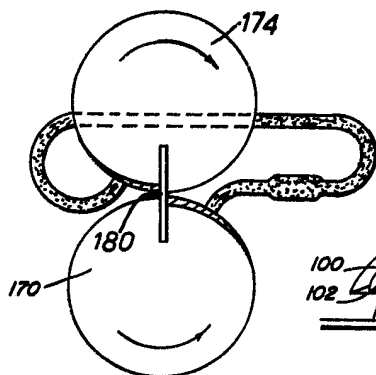


FIG. 12

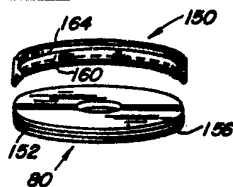


FIG. 13

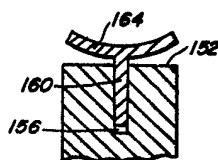


FIG. 14

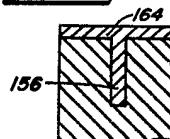


FIG. 15



DERWENT-ACC-NO: 1974-C2607V

DERWENT-WEEK: 197534

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TITLE: Fluid actuated motor or pump consists of two units with a Mobius type single turn vane efficiently intercoupled

PATENT-ASSIGNEE: UNIV NORTHWESTERN[NOUN]

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INT-CL-CURRENT:

TYPE	IPC DATE
CIPS	F01C3/02 20060101

ABSTRACTED-PUB-NO:

EQUIVALENT-ABSTRACTS:

TITLE-TERMS: FLUID ACTUATE MOTOR PUMP CONSIST TWO UNIT MOBIUS TYPE SINGLE TURN VANE EFFICIENCY INTERCOUPLING

DERWENT-CLASS: Q51 Q56